DOCUMENT RESUME

ED 137 093 SE 022 233

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TITLE Language Acquisition as a Byproduct of Science Education.
PUB DATE Mar 77
NOTE 27p.; Paper presented at the annual meeting of the National Association for Research in Science Teaching (50th, Cincinnati, Ohio, March 22-24, 1977)

EDRS PRICE MF-$0.83 HC-$2.06 Plus Postage.
DESCRIPTORS *Cognitive Development; *Educational Research; *Elementary Education; *Elementary School Science; *Inquiry Training; *Instruction; *Language Development; Skill Development
IDENTIFIERS Piaget (Jean); Research Reports

ABSTRACT

Investigated in this study was the relationship between an inquiry approach to science instruction and language development. Four classes of sixth-grade children from two socioeconomic groups participated in the study. The treatment consisted of 12 inquiry film sessions and six discussion sessions, each session 40 minutes in length. At the end of each film session, the students wrote as many hypotheses as they could in 12 minutes. Collected papers were scored on two criteria: (1) the Hypothesis Quality Scale, and (2) the Syntactic Complexity Formula. Results of a statistical correlation study indicated high correlation between hypothesis quality scores and syntactic complexity for treatment groups in both socioeconomic levels. It is concluded that the link between the formation of scientific hypotheses and language development is cognitive development. Implications are discussed regarding the popular view that successful individuals in science are not generally proficient in language-centered activities. (CS)

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LANGUAGE ACQUISITION AS A BYPRODUCT OF SCIENCE EDUCATION

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Paper presented at the 50th anniversary meeting of the National Association for Research in Science Teaching, March 1977.

Cincinnati, Ohio

SE 022 233

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1.0 Introduction

Science education research studies over the past ten years have consistently indicated that young children's participation in science activities has a positive effect on language skills both oral language and reading readiness. Rowe (1968, 1970) found inner city first graders produced 200 percent more spontaneous language during science activities than during so-called language arts instruction. Newman (1970) and Kellogg (1971) found in separate studies that primary grade children given science instruction scored significantly better on reading readiness tests than control groups. Huff and Languis (1973) report an increase in oral communication skills for kindergartners given science instruction. Bethel (1973) found a positive effect of science experiences on oral communication and classification skills for third grade children. In all cases, science experiences were based on an inquiry-approach concerned with processes such as observation, classification, measurement, inferring, and prediction. With the contribution of science instruction to the development of language skills well documented in research studies with young children, various instructional programs have been established utilizing science experiences as the approach to facilitating language acquisition. Among these are the All Indian Pueblo Council-Lawrence Hall of Science Project under the direction of Herbert Thier (1975) and the Hillsborough County Public Schools (1974).

Of the research studies investigating the effects of science education on language development, none have specifically isolated the ability to form hypotheses as a critical component in the inquiry approach to science education and its relationship to the development of language. Furthermore, in examining science education and language developement

relationships, researchers have focused on young children in the first years of schooling. Within a Piagetian framework of cognitive development one may assume the subjects of these studies are generally within the pre-operational or operational stages.

The purpose of this paper is to examine the relationship between science instruction and language development for the older child, specifically 11-year-old sixth graders who, according to Piaget's schema, may be candidates for a transitional stage between operational and formal thought. Rather than examining the range of processes involved in science activities, focus here is placed on the role of hypothesis formation as a central process in the solution of science problems and in the development of language.

The framework for studying the ability of children to form hypotheses is set forth in a study by Quinn (1971,1975), which evaluated a method for teaching hypothesis formation to sixth grade children in two different socio-economic settings. Under the conditions described in that study, Quinn concluded that hypothesis formation can be taught, that the quality of the hypotheses elicited can be measured, that the ability to hypothesize is correlated with IQ, overall grade point average, reading ability, and sex of the student. Evidence from Quinn's study refutes the position that hypotheses formation is intuitive and cannot be taught.

Quinn tested the research hypothesis that there is a difference between the quality of hypotheses formulated by students who received instruction in formulating hypotheses and those who did not. Through a two-by-two factorial design to compare control and treatment, groups, statistical results from an analysis of coveriance demonstrated that treatment was effective at the 0.001 level of significance. In other

words, sixth grade students involved in the study did improve in their ability to hypothesize. They had developed a cognitive skill considered central to the learning of science.

Following the theory current in developmental psycholinguistics that language acquisition results from processes utilizing hypothesis formation and testing to construct an internalized set of rules or grammar of the language, we hypothesize that children specifically taught to improve the quality of their hypotheses formulated in a science class will give evidence of progressing to more sophisticated levels of language development. Furthermore, we hypothesize this development will be observable in sixth grade children since research studies indicate that children of this age have not yet acquired all of the rules of the adult grammar. Chomsky (1969) in a study of monolingual English-speaking children found that children at age 10 have not developed some of the more complex structures of English. Kessler (1971) working with bilingual children found that the upper limits of language acquisition had not taken place in the 9 year olds in her sample. The upper limits of the age at which the adult grammar is fully encoded have not yet been empirically determined. One may, therefore, assume that sixth graders are still developmental in language acquisition.

Edmonds (1976) argues that a satisfactory account of language acquisition will not emerge until this process is examined within a larger developmental perspective. We believe that the ability to formulate hypotheses in a science experience can give insights into that wider perspective of cognitive development which crosses all areas of intellectual development.

Among studies that have examined relationships between language development and cognitive development, Tremaine (1975) found that the comprehension

of syntactic structures in bilingual children is closely correlated with the development of Piagetian intelligence. Ingram (1975) studying children between ages 3 and 12 found that the child's linguistic development as shown in the ability to take into account relationships between sentences is directly analogous to his cognitive development. Also from a Piagetian perspective, studies by Ferreiro and Sinclair (1971) illustrate that the child's ability to perform certain linguistic operations is closely related to cognitive developement.

We believe that the ability to formulate hypotheses in a science experience can give insights into the wider perspective of cognitive development and its relationship to language acquisition. We hypothesize, then that children who give evidence of improvement in the ability to formulate scientific hypothesies will concurrently demonstrate more development in the syntactic complexity of the language used to express those hypotheses. In other words, children taught to form hypotheses will, as a byproduct of that instruction give evidence of higher levels of language development. In addition, we hypothesize this is a universal relationship, operating independently of socio-economic variables. In summary, our research hypotheses are:

1) The level of syntactic complexity of hypotheses formulated by a treatment group given science-based experiences is of a higher order complexity that those formulated by a control group.
2) A positive correlation exists between the quality of scientific hypotheses scores and the syntactic complexity scores for the written language used to express the hypotheses.
3) Positive correlation between the quality of hypotheses formulated and the level of syntactic complexity in the language of those

hypotheses will be maintained regardless of socio-economic variables.

This study also investigates possible correlation between both the hypotheses quality scores and syntactic complexity scores with: (1) IQ as measured by Otis Quick-Scoring Mental Ability Test, Beta, Form FM; (2) reading scores as measured by Part III of the Pupil Progress Series, Diagnostic Reading Test; (3) overall grade-point averages.

2.0 Metholdology

Four intact sixth grades classes participated in the study, one control and one experimental group from each of two socio-economic levels. One control and treatment group were from two classes of 50 students each in a low socioeconomic urban area of Philadelphia, Pennsylvania. (Socio-economic Level 1). The high socioeconomic group (Socio-economic Level 2) was made up of a control and treatment group, 32 students in each, from an upper middle class suburban area of Philadelphia.

The treatment consisted oa 12 science inquiry film sessions and 6 discussion sessions, each session 40 minutes in length. The problem-presentation sessions were based on film loops of the Inquiry Development Program in Physical Science developed by Suchman (1962). Each 3-minute film loop depicts a single physical science problem. At the end of each science inquiry film session the students wrote as many hypothese as they could in a rigorously controlled 12-minute period. The collected papers were then scored on two criteria: The Hypothesis Quality Scale developed by Quinn (1971) and the Syntactic Complexity Formula developed by Botel, Dawkins and Granowsky (1973). The Hypothesis Quality Scale is given in Table 1.

INSERT TABLE 1

To determine the reliability of the Hypothesis Quality Scale, a set of 50 hypotheses taken from those written by the sixth grade children in the study were given to three science educators who assigned scores using Quinn's scale. The Nash-Beyers (Winer 1962) computer program for inter-judge reliability gave an unadjusted reliability coefficient of 0.94, establishing the reliability of the scale.

The Botel-Dawkins-Granowsky measure of syntactic complexity was selected from among others because of the theoretical basis on which it was established and because of the ease with which it can be used by the non-linguist. The formula is derived from transformational-generative grammar theory. Furthermore, it takes into account language development and performance studies which consider the frequency of usage of structures in children's oral and written language as well as experimental data on children's processing of sytactic sturctures. In applying the formula, syntactic structures are assigned weighted scores ranging from 0 to 3. One significant feature of the Botel-Dawkins-Granowsky formula is that syntactic maturity or complexity is a function of specific structures rather than sentence length.

To determine the reliability of the Syntactic Complexity Formula the same set of 50 hypotheses used in determining the interjudge reliability of the Hypothesis Quality Scale was given to four judges. The Nash-Beyers computer program for interjudge reliability gave an unadjusted reliability coefficient of 0.98.

Following each set of two film sessions, one of the investigators conducted a discussion session which focused on teaching the children how to formulate good hypotheses. During these sessions, the investigator interacted with the children by asking what they observed, inferred, and what changes in physical conditions took place during the film. Both statements given by the children and some of the hypotheses they had written during the film sessions were written on the blackboard. The investigator then applied the Hypothesis Quality Scale to these statements to show the children how to judge their own hypotheses and how to make use of their observations and inferences to generate ones of higher quality. Children in the treatment group consequently learned to distinguish between a 0-value hypothesis as 'Magic did it' and a 5-value one, the highest score on the scale, as 'I could test my idea by putting severl little bottles with different amounts of water in them in a tub and then seeing which ones would sink.'

At the end of the treatment, three additional film sessions were presented to elicit hypotheses that were scored in order to obtain the criterion variable of the treatment group. The same films were presented to the control group to elicit hypotheses for the criterion variable for that group. The hypotheses generated under these conditions provide the raw data for the present study.

3.0 Results

Means and standard deviations for the five variables considered for the control and treatment groups of both the upper and lower socio-economic groups are given in Tables 2 and 3.

INSERT TABLE 2

Closely matched for IQ, reading comprehension and grade-point average, the treatment and control of the upper socio-economic groups demonstrate marked differences in hypothesis quality and written language complexity. The group receiving instruction in science focusing on problem-solving situations scored considerably higher in the quality of their hypotheses and the complexity of the language used to express those hypotheses.

INSERT TABLE 3

Also matched for IQ, reading comprehension, and grade-point average, although all three variables are somewhat below those of the upper socio-economic group, the treatment and control groups for the lower socio-economic groups also demonstrate considerable gains in the quality of hypotheses formulated and in the complexity of the language used to express them.

Correlation matrices examine the relationship between the quality of hypothesis scores (HYPO), the level of synthactic complexity of the hypotheses (LANG) and the additional variables of reading comprehension (READ), IQ, and grade-point average (GRA). Table 4 gives correlations for the upper socio-economic control group.

INSERT TABLE 4

Hypothesis quality and syntactic complexity of language correlate more positively with each other than with any of the other three variables: reading, IQ, and grade-point average. Table 5 gives the correlation matrix for the treatment group of the upper socio-economic group.

INSERT TABLE 5

It can be observed from Table 5 that the highest positive correlation is found between hypothesis quality and language development rather than with any of the other three variables. In other words, as children learn to formulate better hypotheses, the level of language development increses. The slightly lower Pearson product moment correlation coefficient for the treatment group is undoubtedly attributable to the scoring procedures used in determining hypothesis quality and syntactic complexity. The scores of 0 through 5 for the Hypothesis Quality Scale are not equal interval scores; the scoring procedure for syntactic compexity is open-ended. In spite of the procedural differences in calculating hypothesis quality and syntactic complexity, a positive correlation is evident.

Table 6 gives the correlation matrix for the lower socio-economic control group.

INSERT TABLE 6

Just as for the upper socio-economic group, it can be observed that the highest positive correlations for both hypothesis quality and language development occurs between these two variables rather than with reading comprehension, IQ, or grade-point average. Table 7 presents correlations for the lower socio-economic treatment group.

INSERT TABLE 7

The lower socio-economic treatment group, just as the control group, shows the highest positive correlations for both hypothesis quality and language development occurs between these two variables rather than with reading comprehension, IQ, or grade-point average. In other works, the pattern observed for the upper socio-economic group is also observed for the lower socio-economic group.

Table 8 combines both economic groups in examining the level of significance for correlation coefficients between hypothesis quality scores and those measuring levels of syntactic complexity.

INSERT TABLE 8

With the level of significance for correlation coefficients for hypothesis quality with syntactic complexity at 0.001 for control and treatment groups at both the upper and lower socio-economic levels, it becomes evident that the quality of scientific hypotheses generated in problem-solving situations is directly correlated with the complexity of the language used in expressing those hypotheses.

Figure 1 summarizes the findings of this study for the relationship between gains made in hypothesis qulity scores and those for written language sytactic complexity for the control and treatment groups of the two socio-economic levels.

INSERT FIGURE 1

Hypothesis quality scores are consistently higher for the treatment groups at both socio-economic levels than those for the control groups. The same relationship holds for the level of written language complexity.

In both hypothesis quality and syntactic complexity, the upper socio-economic group starts at somewhat higher levels than does the lower socio-economic group, but both show positive correlations on both variables.

4.0 Implications

Results of a statistical correlation study of two sets of raw data, hypothesis quality scores and syntactic complexity, for control and treatment groups at each of two socio-economic levels indicate high positive correlation between the two measures. Specifically, it was found that as children improve in the cognitive process of hypothesizing their language becomes syntactically more complex. This relationship occurs without any direct effort to teach language. In other words, language development results as a byproduct of science education. It can further be concluded that the link between the formation of scientific hypotheses and language acquisition is cognitive development.

The implications for psychologists, science educators, linguists, science teachers, language teachers, and elementary school teachers are profound. Certainly the popular view that an individual who is very successful in science is generally not proficient in language-centered activities is challenged.

If hypothesis formation is correlated with cognitive development, as conceptualized by Piaget, for example, and cognitive development is correlated with language acquisition, then it is possible to conclude that hypothesis formation and language development are logically related. As conceptual development takes place, one may expect a facilitating interaction between the ability to hypothesize and the level of language development. Data from this study indicate that this interaction occurs regardless of socio-economic levels of the child. If young children involved in a science activity program, making use of the inquiry or

process approach, generate more complex syntactic structures, one may expect these same children to read better, to achieve better in any language-based activity than children who have not had a similar science experience. Reading, in other words, need not be separated out from the teaching of other content areas in the curriculum.

An implication critical for current educational concerns involves findings of this study for bilingual education. If science education facilitates acquisition of the first language, as this study shows, it can be assumed that science experiences also facilitates acquisition of two languages in a bilingual instructional setting. Science-based activities such as those on which this study is based provide the conditions under which language acquisition both first and second is facilitated. High positive correlations between hypothesis aquality and language development as those obtained in this study, regardless of socio-economic level of the children, indicate that the same positive correlations may be expected in a bilingual situation in which two languages are under development. This is, of course, a research question. Experimental evidence such as that obtained from the Redwood City Bilingual Project for Mexican-Americans as reported in Cohen (1975) strengthens this position. Children in the bilingual treatment group appear to have developed nonverbal reasoning powers to a degree significantly higher than that of the control group. In other words, a bilingual approach to instruction develops the cognitive functioning of its participants to a degree equal to or greater than a monolingual control group.

In the Edgewood Independent School District of San Antonio, Texas, we have developed a set of guidelines for bilingual instruction in science through the NIE-supported Experimental School Plan. From the findings of the study reported in this paper it is our prediction that implementation of such

a bilingual science program will facilitate the the acquistion of two languages, in this case Spanish and English, for children from a low socio-economic group. The Edgewood School Plan, as the NIE project is termed, is concerned with bilingual education of Mexican-American children who are in various stages of development for the first and second languages. The effects of science education on language development, regardless of socio-economic level, as we have reported in this paper give evidence that science instruction is a crucial curriculum component in bilingual education programs, that it can play a central role in the language development of the participants, both in regard to the first language as well as the second. Clearly, further research is needed, but evidence from a study such as the one reported here supports the theory that the development of two languages in a child increases cognitive development, which in turn facilitates further language acquisition. The inquiry-based approach to science education we have developed for the Edgewood School Plan provides the types of experiences we feel are necessary for the concurrent development of language to take place in the child.

Results of this study imply that a science curriculum which facilitates conceptual development as measured by the ability to formulate scientific hypotheses in turn facilitates language development. Rather than teaching the structure of a language directly, making science experiences of the type described in this study available to the learner will, as a byproduct, provide the conditions under which language acquisition is facilitated.

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APPENDIX

TABLE 1

HYPOTHESIS QUALITY SCALE

SCORE	CRITERION
0	NO EXPLANATION, SUCH AS, A NON-SENSE STATEMENT, A QUESTION, AN OBSERVATION, A SINGLE INFERENCE ABOUT A SINGLE CONCRETE OBJECT.
1	NON-SCIENTIFIC EXPLANATION, SUCH AS, '...BECAUSE IT'S MAGIC' OR '...BECAUSE THE MAN PUSHED A BUTTON.'
2	PARTIAL SCIENTIFIC EXPLANATION, SUCH AS INCOMPLETE REFERENCE TO VARIABLES, A NEGATIVE EXPLANATION, AN ANALOGY.
3	SCIENTIFIC EXPLANATION RELATING AT LEAST TWO VARIABLES IN GENERAL OR NON-SPECIFIC TERMS.
4	PRECISE SCIENTIFIC EXPLANATION, A QUALIFICATION AND/OR QUANTIFICATION OF THE VARIABLES.
5	EXPLICIT STATEMENT OF A TEST OF AN HYPOTHESIS. (AN INFERENCE IS MADE HERE THAT THE CHILD WHO STATES A TEST IS ALSO ABLE TO ADEQUATELY AND PRECISELY HYPOTHESIZE.)

TABLE 2

MEANS AND STANDARD DEVIATIONS
UPPER SOCIO-ECONOMIC GROUP

VARIABLE	CONTROL		TREATMENT	
	MEAN	SD	MEAN	SD
HYPOTHESIS QUALITY	25.4	11.4	53.3	21.5
WRITTEN LANGUAGE COMPLEXITY	52.6	25.4	130.0	43.5
INTELLIGENCE QUOTIENT	108.9	21.7	110.7	10.8
READING	67.2	15.8	70.1	12.0
GRADE-POINT AVERAGE	79.2	15.5	80.2	6.1

TABLE 3

MEANS AND STANDARD DEVIATIONS
LOWER SOCIO-ECONOMIC GROUP

VARIABLE	CONTROL		TREATMENT	
	MEAN	SD	MEAN	SD
HYPOTHESIS QUALITY	15.7	8.7	42.8	23.5
WRITTEN LANGUAGE COMPLEXITY	36.3	15.2	83.2	41.6
INTELLIGENCE QUOTIENT	101.2	9.4	103.1	11.7
READING	57.7	15.4	57.8	14.9
GRADE-POINT AVERAGE	77.0	8.5	77.8	7.8

TABLE 4

CORRELATION MATRIX FOR THE CONTROL GROUP
UPPER SOCIO-ECONOMIC GROUP

	HYPO	LANG	READ	IQ	GPA
HYPO	1.00	0.87	0.62	0.57	0.53
LANG		1.00	0.55	0.51	0.52
READ			1.00	0.88	0.89
IQ				1.00	0.95
GPA					1.00

TABLE 5

CORRELATION MATRIX FOR THE TREATMENT GROUP
UPPER SOCIO-ECONOMIC GROUP

	HYPO	LANG	READ	IQ	GPA
HYPO	1.00	0.71	0.44	0.51	0.65
LANG		1.00	0.57	0.53	0.68
READ			1.00	0.74	0.70
IQ				1.00	0.84
GPA					1.00

TABLE 6

CORRELATION MATRIX FOR THE CONTROL GROUP
LOWER SOCIO-ECONOMIC GROUP

	HYPO	LANG	READ	IQ	GPA
HYPO	1.00	0.60	0.28	0.22	0.44
LANG		1.00	0.25	0.10	0.44
READ			1.00	0.67	0.75
IQ				1.00	0.70
GPA					1.00

TABLE 7

CORRELATION MATRIX FOR THE TREATMENT GROUP
LOWER SOCIO-ECONOMIC GROUP

	HYPO	LANG	READ	IQ	GPA
HYPO	1.00	0.65	0.46	0.44	0.59
LANG		1.00	0.38	0.28	0.57
READ			1.00	0.77	0.69
IQ				1.00	0.76
GPA					1.00

TABLE 8

LEVEL OF SIGNIFICANCE FOR CORRELATION COEFFICIENTS

VARIABLES	UPPER SE		LOWER SE	
	CONTROL	TREATMENT	CONTROL	TREATMENT
HYPOTHESIS WITH LANGUAGE	0.001	0.001	0.001	0.001

FIGURE 1

COMPARISON OF GAINS IN HYPOTHESIS QUALITY AND WRITTEN LANGUAGE FOR TWO SOCIOECONOMIC GROUPS